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Quarterly Technical Summary

Educational Technology Program

15 June 1971

Prepared under Electronic Systems Division Contract F19628-70-C-0230 by

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts

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ABSTRACT

Work during this quarter was devoted largely to experimental verification and refinement of design details for LTS-3. A series of meetings with personnel from the 3380th Technical Training School firmed up schedules, procedures and lesson materials for the Keesler trials, which are now scheduled for early in the third quarter of FY 72.

15 June 1971

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Program Manager

Accepted for the Air Force
Joseph R. Waterman, Lt. Col., USAF
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EDUCATIONAL TECHNOLOGY PROGRAM

I. EDUCATIONAL DEVELOPMENT PROGRAM FOR LTS

A. The Keesler Trial

The Keesler Technical Training School made steady progress preparing one-week lessons in the area of electronics and in air traffic control. There were visits and conferences to work out procedural details and instructional methods. The Keesler personnel are responsible for the design and preparation of course materials. Lincoln instructed them on the capabilities of the machine and modified the software design to accommodate the exact form of student response interpretation that the course authors demand. The procedures for preparation and revision of course material were altered substantially several times in response to hardware problems. These changes appear to have stabilized and a mutually satisfactory arrangement was agreed upon.

B. Educational Techniques

The greatest challenge in educational technique comes in the electronics course where the learning is largely conceptual, rather than in the air traffic control course where it is largely factual.

A pretest that is roughly one-quarter verbal, one-quarter electronics knowledge and one-half general mathematics will be given to students in the electronics course. Those who pass (approximately 25 percent) will be assigned to a self-paced program using conventional materials, while those who fail will become students in the trial.

The most abstract material in the electronics course is an introduction to AC circuit theory. It demands a reasonable grasp of elementary algebra and vector theory. The instructional strategy being implemented is to present many problems on each kind of circuit to be solved. Mistakes will be fielded according to type – choice of formula, calculated value, unit of measurement, etc., with appropriate remediation provided in each case. The hope is that the few students who learn principles can generalize from one circuit to another, solve problems correctly and therefore make rapid progress. Those who learn about each circuit separately and develop principles inductively will proceed at a slower pace. Finally, there are students who will not learn the concepts at all. They memorize procedures for each kind of circuit; therefore they must work many problems and must be conditioned to avoid each kind of error. The general technique, one of monitoring problem-solving behavior, has been employed very successfully in the conventional classroom in the same part of the electronics course. It seems particularly appropriate for application to LTS.

C. Lincoln Training Language (LTL)

During this quarter, development of a special language for a processor to support LTS was begun. This language must meet the following three requirements.

(1) It must be possible to implement the hardware for the language processor at minimum cost. A future version of LTS envisions a stand-alone machine with modest logical hardware. The present design looks forward to that eventuality.

(2) LTL must be a compact form of code that can be interpreted even by a non-programming author.

(3) Finally, LTL must provide the author with versatility in the interpretation of human response. It must also provide control functions and student record keeping in the classroom.

Some of the instructions in LTL control the machine by selecting a new frame, turning the picture and sound on and off, setting a timer, etc. Other instructions interpret key presses, i.e., student responses. The basic instruction is a branch on a response; thus the language is similar to the character processing languages provided in some large computers. A subroutine of branch instructions is used to interpret strings of responses, such as in composite multiple choice. In this way errors are diagnosed and branches are conditioned by the kind of error.

It is not likely that Version I of the language is going to serve all the long run requirements of LTS. Redesign will be a part of the continuing LTS development effort.

II. HARDWARE DEVELOPMENT

During this quarter a breadboard audio-reader system was constructed and tested, allowing us to measure and evaluate the full LTS-3 audio system, including microfilm. We have designed the LTS-3 microfiche card format to support 12 audio-graphic frames per 4 × 6-inch film card.

A. Terminal Design

Modification of the Image Systems, Inc. Model 201 CARD Reader, to include a dual optical imaging system, continued during this quarter. A pictorial view of the reader with the added audio-reader system is shown in Fig. 1.

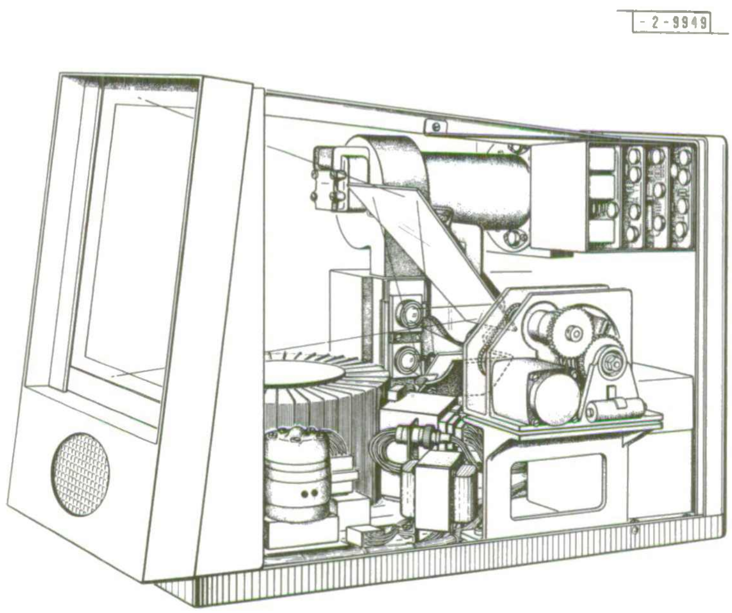


Fig. 1. Pictorial view of modified CARD reader.

B. Console Design

The console for LTS-3 will consist of two parts, the display unit and the student table. The display unit includes the modified Image Systems fiche projector mounted on top of a cabinet, which contains power supplies and other electronic units, as well as the light source for both visual and audio projectors. It is on wheels so that it can be moved back from the student table easily for maintenance and repair. The student keyboard, the display controls (FOCUS, VOLUME, etc.), a small speaker and a phone jack are located on the panel below and in front of the screen, almost flush with the student work surface. This unit is readily removed for access to the fiche selection keyboard in back, which is used only for maintenance work. The display surface is 8×10 inches, providing essentially a full-sized image of the original material. The screen is also an access door. It can be opened by the instructor to install and replace new fiche in the fiche carousel. As a whole, this terminal is bulky; it is an experimental terminal and for the moment, ease of construction, access and maintenance were considered to be more important than compactness, portability, cost and other design factors.

The Keesler Technical Training Center has agreed to build the student carrels that will accommodate the machines, and provide power outlets and a work surface to support student projects. They intend to present instructions and illustrations on LTS to guide this kind of student activity. The design of the final form of the display unit has just begun; when complete in 4 to 5 weeks it will be forwarded to KTTC for design of the student stations.

C. Audio Recording System

The master film recording system described in the last quarterly technical summary (15 March 1971) produces a variable-width modulated track using a recording optical galvanometer, shown schematically in Fig. 2. The output light beam is imaged onto the film with unmodulated beam dimensions of $2.5 \times 254\,\mu m$. The audio signal modulates the long dimension

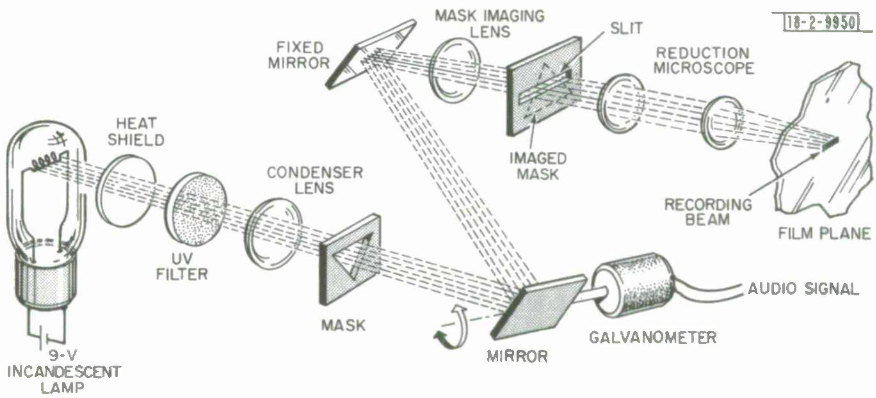


Fig. 2. Recording galvanometer – schematic.

symmetrically about its mean value, producing an exposed negative image as shown in Fig. 3. The film is rotated at 60 rpm, and the galvanometer is driven radially at 0.82 mm/sec to produce a spiral record as shown in Fig. 4. The performance characteristics of the optical recording system are:

Optical output	1.6×10^{-6} W
Power density	$254\, mW/cm^2$
Frequency/phase response	see Fig. 5
Amplitude distortion	< 0.1 percent

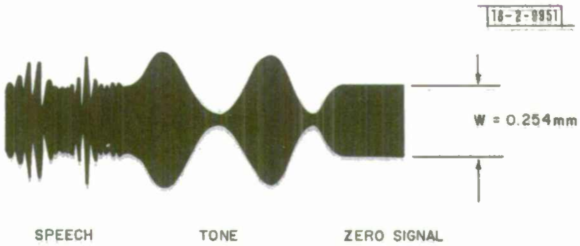


Fig. 3. Recording galvanometer track format.

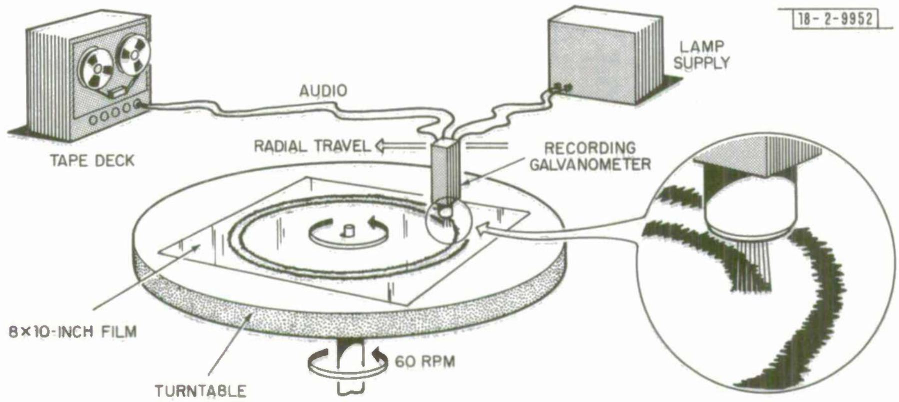


Fig. 4. Area modulation film recorder.

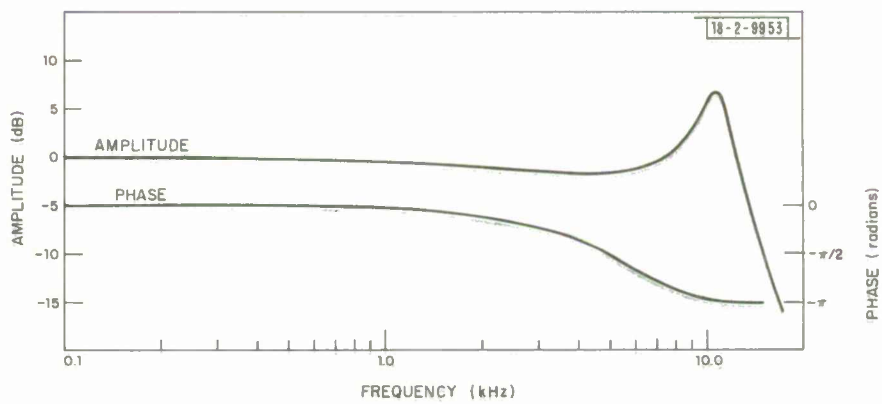


Fig. 5. Recording galvanometer frequency and phase response.

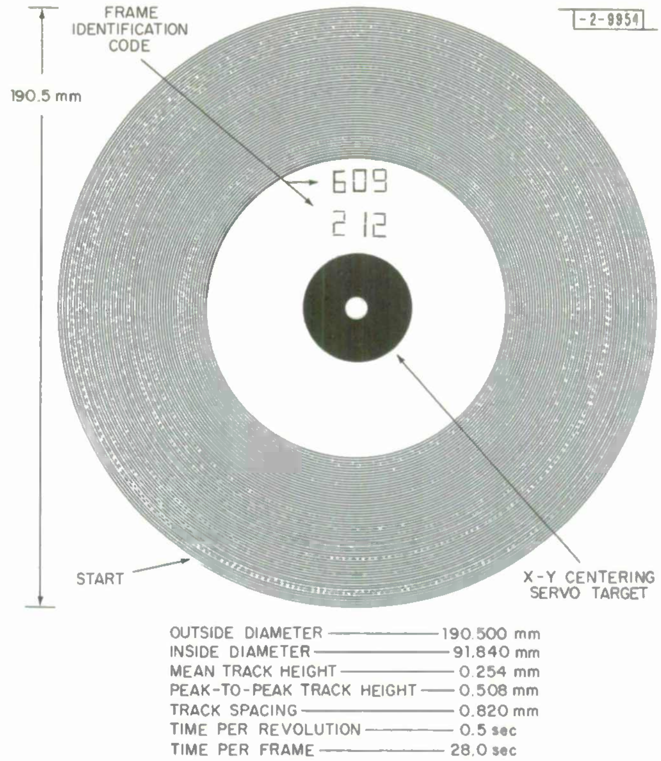


Fig. 6. Original master audio frame.

An original master audio frame is shown in Fig. 6. This record includes numerical identification and a boresight target for automatic alignment in the audio-reader system. The record is reduced by 8.70:1 onto the microfiche master film.

D. Audio Reader System

The breadboard audio-reader system is shown schematically in Fig. 7. The present assembly rotates at 60 rpm, but is being modified to operate at 120 rpm. The discussion will refer to recorded track format and reader diode apertures for this speed. A quartz-iodide incandescent source is used to illuminate both the video image and audio spiral records, using a bifurcated fibre light guide. The condenser system is designed to provide uniform illumination of the image Intensity variations over the audio field are less than ±25 percent. The audio system projection lens is a 25 mm f/4, camera lens. The modulation transfer function (MTF) of the audio projection system is shown in Fig. 8.

The audio spiral image is projected onto the plane of the reader and magnified in size by 5.66:1. The signal/tracking head assembly is shown schematically in Fig. 9. Two versions of the track/read head assembly are being constructed. One unit has the photo-diodes on the head assembly, with their photo-sensitive regions as shown in Fig. 9(a). The other unit uses a fibre-optics assembly, shown schematically in Fig. 9(b), to conduct the signals to photo-diodes mounted on the fixed electronics board.

The head is rotated at 120 rpm, using a synchronous drive assembly, and caused to track the spiral record by a rate-aided servo system which derives tracking error signals from the differential apertured photo-diodes, oriented normal to the track. This keeps the spiral track

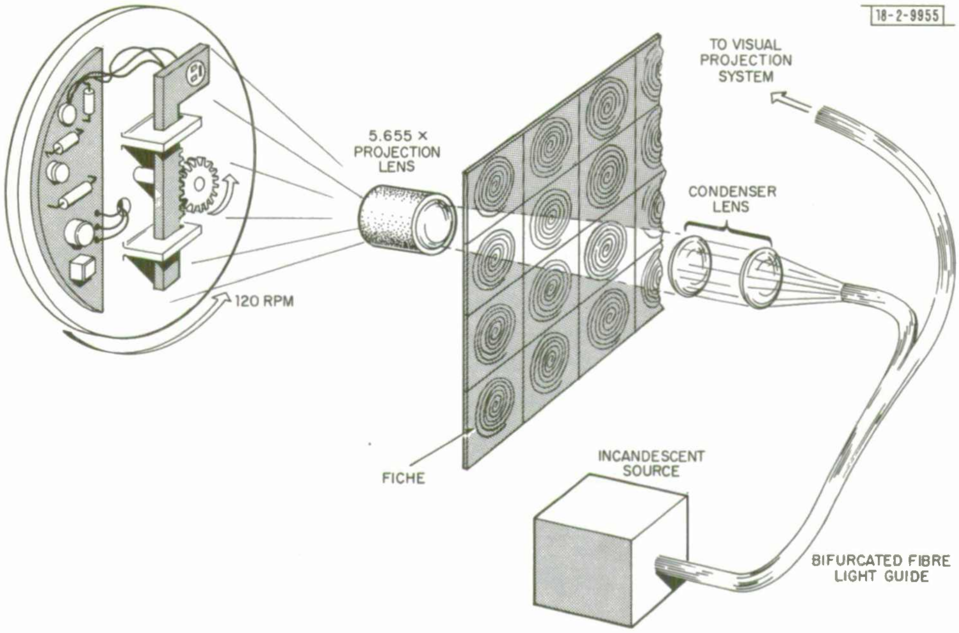


Fig. 7. Audio reader system.

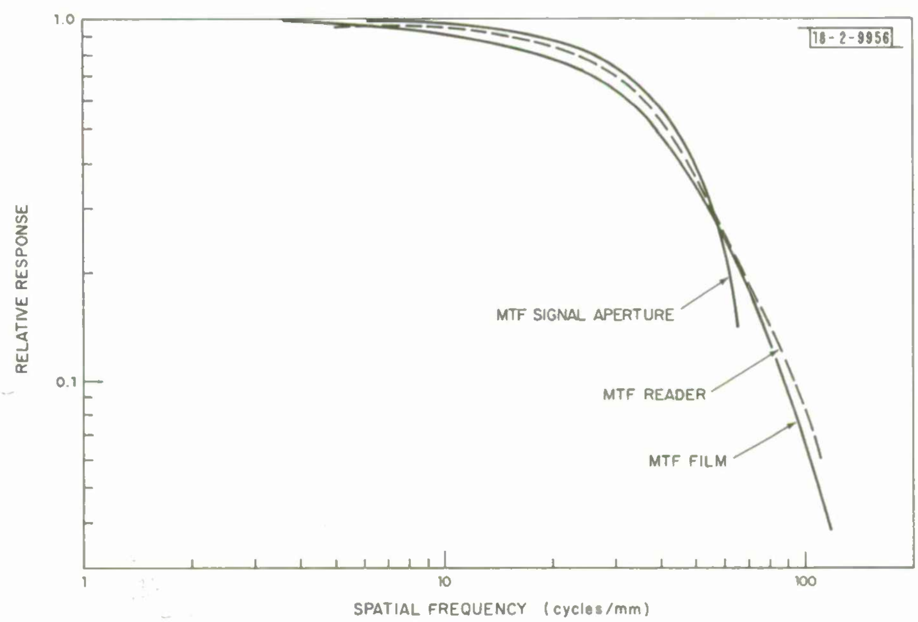
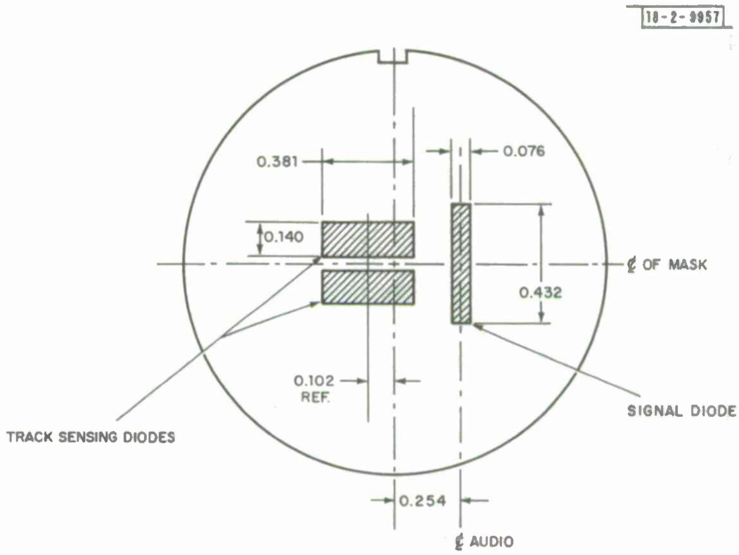
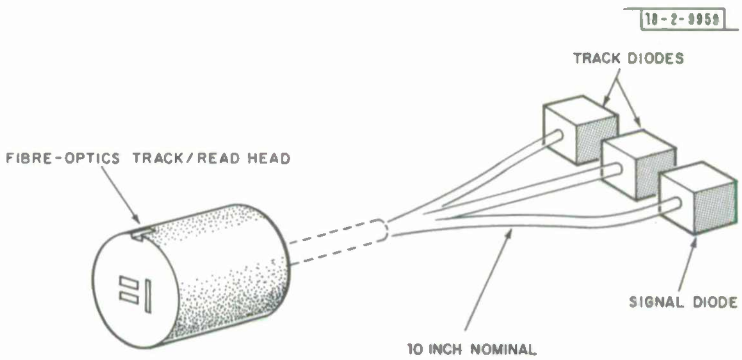


Fig. 8. Modulation transfer function: reader system components.



(a)



(b)

Fig. 9. Track/read head assembly: (a) diode; (b) fibre-optics.

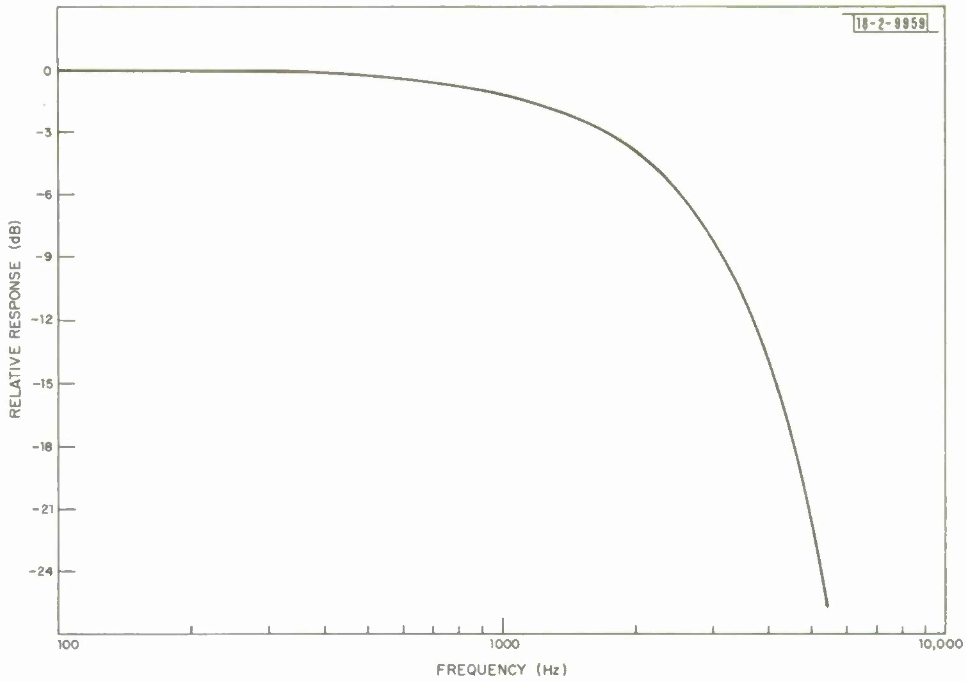


Fig. 10. Audio-reader system: frequency response without compensation.

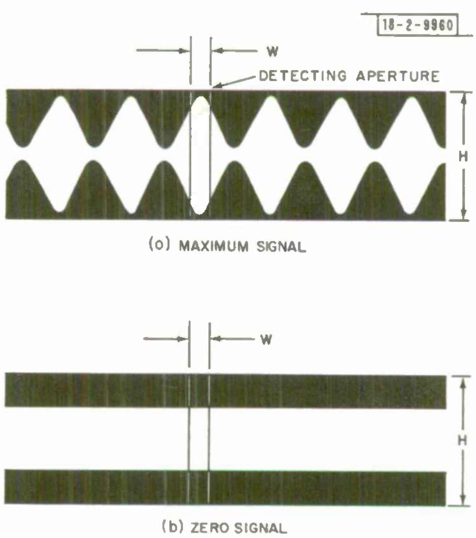


Fig. 11. Area modulated film.

centered on the signal aperture. Variations in transmittance are detected as signal. The MTF of the signal aperture is shown in Fig. 8. Typical MTF of the final film record, which includes 8.7:1 reduction of the master and contact printing, is also shown. The frequency response of the record/reproduce system (for a median track velocity of 110 mm/sec) is shown in Fig. 10. High frequency pre-emphasis will be used to achieve a relatively flat response in the band 300 to 3300 Hz.

Measured system peak signal to rms noise (3 kHz bandwidth) has been in good agreement with computed values for the copy films used to date. In general, high resolution, low granularity films have been used. Signal-to-noise ratios have been in the range +26 to +43 dB. Film S/N ratio depends upon the transmittance modulation of the signal on film vs the statistical properties of the emulsion grains. For a variable area modulated signal as shown in Fig. 11, the maximum average signal power to zero signal noise power, assuming a dense dark area, is given by the expression

$$\frac{S}{N} = \frac{1}{2}\left(\frac{(\overline{T})^2}{\sigma_{TH}^2}\right) \tag{1}$$

where $\overline{T}$ is the average film transmittance and is related to the average density by the relationship

$$\overline{D} = \log_{10}\frac{1}{\overline{T}} \tag{2}$$

and σ_{TH} is the rms variation in transmittance measured over 1/2 a slit height under zero signal conditions. In practice, the rms variation in density σ_D is specified in film data sheets. The variation in density is usually specified for an average density of unity for a 48 µm diameter aperture and is called the rms granularity which we define as σ_G. For small σ_D it can be shown that the relationship between σ_D and σ_T is given by

$$\sigma_D = 0.43\,\frac{\sigma_T}{\overline{T}} \quad . \tag{3}$$

The relationship between σ_D and the area A of the measuring aperture is given by

$$\sigma_D^2 \,\alpha\, \frac{1}{A} \quad . \tag{4}$$

Experimental data show that

$$\sigma_D^2 \,\alpha\, \overline{D} \quad . \tag{5}$$

Combining these results we obtain, at an average film density of 0.25, the following approximate expression for S/N ratio in terms of σ_G, the rms granularity specified in film data sheets and the dimensions of the scanning aperture (Fig. 11)

$$\frac{S}{N} \approx \frac{10^{-4}\,HW}{\sigma_G^2} \quad . \tag{6}$$

TABLE I S/N FOR HIGH RESOLUTION FILM		
Film	σ_G	S/N
Kodok Minicard	$<4.0 \times 10^{-3}$	>38 dB
Recordak AHU microfilm	6.5×10^{-3}	34 dB

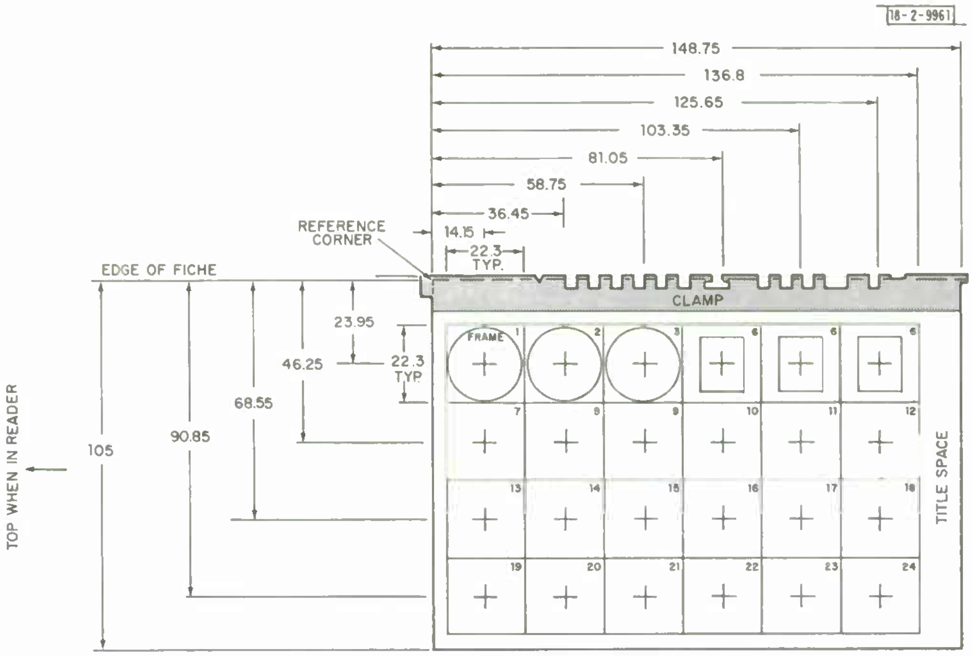


Fig. 12. LTS-3 microfiche cord format – right reoding emulsion side, looking toward light source (dimensions in millimeters).

For the LTS-3 reader whose slit area is on the order of 1000 square microns

$$\frac{S}{N} \approx \frac{10^{-1}}{\sigma_G^2} \quad . \tag{7}$$

Table I shows computed S/N for two high resolution films, using LTS-3 parameters.

E. LTS-3 Terminal/Computer Interface

During this quarter a portion of the LTS-3 I/F subsystem was completed, and used to demonstrate computer control of the Model 201 CARD reader. Sufficient bits were implemented to permit random access to 35 frames/card for nine microfiche cards. The reader is presently being operated under computer control on a "life test" in which it is cycled through three cards in a 300 second period and is stepped through 23 frames/card. To date the reader has made 8000 card changes and projected 180,000 frames without failure. The final portion of one LTS-3 Terminal/computer I/F is 90 percent complete. System testing will begin during July.

One LTS-3 20-key keyboard has been designed, constructed and tested. Construction of keyboards for the five Keesler AFB terminals is under way.

As described in the last quarterly technical summary (15 March 1971), computer I/O Channel 6, for each student terminal, will be used to signal the computer of a fiche card change. The action will be conveyed to the computer by the setting of the Channel 6 interrupt flag. On replying to the interrupt, the computer will transfer and examine bits AC0 and AC1 to determine the machine status. A "one" in bit AC0 will indicate the loading of a fiche card is completed. A "one" in bit AC1 however will indicate that after three revolutions of the card carousel, the machine was unable to locate the card last commanded and in this condition will be in "LOAD" status with no fiche card in the display platen. The Channel 6 response time to a fiche card command will generally be from 1 to 4 sec for the first condition (proper loading) and approximately 6 sec for the latter response.

F. Author's Voice/Data Merge Facility

During the early phase of the field trials, lesson branching logic will be stored on magnetic tape for transfer into computer core memory. The author's audio recording facility will therefore not merge voice and branching logic as reported in the last quarterly technical summary (15 March 1971). This feature will be implemented after the start of field trials. Only the low data rate FSK modem will be implemented to record Pause/Complete functions.

G. LTS-3 Microfiche Format

The detailed dimensions of the LTS-3 microfiche card format are shown in Fig. 12. Video and audio master/negative film transparencies will be reduced by 8.7:1 onto a master microfiche film using a step-and-repeat camera system. The master will be used to produce contact copies on diazo or silver halide films for use in the student terminals. It is intended that frame centers be within ±0.25 mm of nominal position in either dimension for automatic acquisition and tracking of the audio record and for alignment of the video image on the rear projection screen. Measurements to date indicate that the resolution of the contact copies will be equal to or greater than 150 line pairs per mm.

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13. ABSTRACT

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14. KEY WORDS

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